REPORT OF COOPERATIVE RESEARCH ON INSECT CONTROL IN FARM STORED GRAIN

No. 4 Period--April 1 to June 30, 1942

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Corn Storage

Effect of Temperature on Insect Abundance*

In our last report information was included regarding grain temperatures in March in 130 corn bins scattered over the Commercial Corn Area, together with winter survival records of the insect populations of these bins. During April a survey of corn bins was conducted in localities in the Commercial Corn Area, other than those considered in the last report, in order to supplement this information.

The results of this April survey are tabulated in tables 1 and 2, and items of interest are summarized in the following comments:

1. The highest mean temperatures were observed in those bins located in the southern part of the area, while those in the northern portions were much lower. The range of temperatures observed varied from a high of 50° F. in Brown County, Kansas, to a low of 33° F. in Kandiychi County, Minnesota. Temperatures were taken at five levels in the centers of the bins--floor, 3 ft., 6 ft., 9 ft., and 12 ft. above the floor.

2. More than three-fourths of the living insects occurred in the upper half of the bins.

3. In the northern localities the intensity of insect infestation was much less than in the southern portions of the region.

4. In general the corn was in good condition, except in certain bins where surface accumulation of moisture has caused crusting and consequent spoilage of the grain. The amount of spoilage, however, was limited to a few bushels on the surface, even in the most severely affected bins. All of the samples graded No. 1 or No. 2.

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* Reported by H. H. Walkden, J. M. Magner, and R. B. Schwitzgebel, in cooperation with the Bureau of Agricultural Chemistry and Engineering and State Entomology Departments of Illinois, Iowa, Nebraska, and Minnesota.

5. The percentage of living insects varied from none in Traverse County, Minnesota, to 35% in Dodge County, Nebraska, the average for the area being 13%. It should be borne in mind that while these figures give some idea of survival, the number of dead insects found may represent an accumulation over a considerable period of time. Consequently, the actual winter survival was no doubt somewhat greater than the figures indicate. The corn in most of the bins had not been turned or cleaned since the bins were filled, and yet heavy infestations were observed in only two localities--Henry County, Iowa, and Christian County, Illinois.

6. Of the 14 species of living stored grain insects found in the survey, the flat grain beetle and the sawtoothed grain beetle were the most abundant.

Table 1: -- Temperature and Insect Infestation in Corn Stored in Steel Bins in the Commercial Corn Area, April, 1942.

Locality		No. bins sampled	Vertical column in center of bin: Temperature °F: Max.	Min.	Mean	Insect infestations: Upper half: live	dead	Lower half: live	dead	Total insects	Percent living
State	County										
Minn.	Kandiyohi	5	38	28	33.3	5	59	1	4	69	8.7
"	Murray	4	41	30	34.0	0	3	1	1	5	20.0
"	Traverse	2	38	34	35.6	0	0	0	0	0	0
Iowa	O'Brien	8	39	33	35.4	34	97	4	18	153	24.8
"	Floyd	7	39	33	36.1	23	119	31	155	328	16.5
"	Page	7	44	35	38.1	10	157	3	2	172	7.6
"	Henry	7	44	37	39.7	85	135	35	153	408	29.4
Nebr.	Dodge	9	53	35	40.0	72	72	2	63	209	35.4
"	Gage	5	54	39	43.2	5	41	1	65	112	5.3
Ill.	Cgle	11	44	36	40.7	10	95	1	70	176	6.2
"	Peoria	10	54	39	43.5	15	171	6	183	375	5.6
"	Christian	10	52	42	46.2	138	1054	50	619	1861	10.1
Kans.	Doniphan	10	53	42	48.3	14	153	0	6	173	5.1
"	Brown	10	54	46	49.9	42	204	0	147	393	10.6
Totals		105				453	2360	135	1486	4434	13.3

Table 2: -- Species of stored grain insects found in survey of corn bins in the Commercial Corn Area, April, 1942.

Species	Location in bin: Center- Upper half: Living No.	Living %	Dead No.	Center- Lower half: Living No.	Living %	Dead No.	Totals: Live No.	Dead No.	Total	% Live
Flat grain beetle	142	63.3	82	33	53.2	29	175	111	286	61.1
Sawtooth grain beetle	89	20.3	349	84	44.0	107	173	456	629	27.5
Cynaeus angustus	71	37.0	121	2	30.0	5	73	126	199	36.6
Rust-red flour beetle	49	3.4	1377	12	1.1	1115	61	2492	2553	2.3
Dermestids, spp.	53	86.9	8	1	100.0	0	54	8	62	87.0
Cadelle	22	91.6	2	0	0	0	22	2	24	91.6
Indian meal moth	9	12.1	65	0	0	0	9	65	74	12.1
Small-eyed flour beetle	6	100.0	0	1	25.0	3	7	3	10	70.0
Foreign grain beetle	4	1.2	314	0	0	214	4	528	532	0.8
Rice weevil	3	60.0	2	0	0	1	3	3	6	50.0
Black flour beetle	3	43.0	4	0	0	1	3	5	8	37.5
Coninomus sp.	1	50.0	1	1	100.0	0	2	1	3	66.6
Typhaea stercorea	0	0	24	1	11.0	8	1	32	33	3.0
2-Banded fungus beetle	1	50.0	1	0	0	1	1	2	3	33.3
Granary weevil	0	0	9	0	0	0	0	9	9	0
Platydema sp.	0	0	1	0	0	0	0	1	1	0
Mycetophagus sp.	0	0	0	0	0	1	0	1	1	0
Crytophagus sp.	0	0	0	0	0	1	0	1	1	0
Totals	453	16.1	2360	135	8.3	1486	588	3846	4434	13.3

Corn Studies in Illinois*

Infestation

The flat grain beetle survived the winter in greater numbers than any other insect found in steel bin corn in Illinois. It was followed closest by the sawtoothed grain beetle, and by smaller numbers of cadelle fungus beetles and the foreign grain beetle.

Moderate numbers of Indian meal moth adults and larvae are present in a few scattered bins throughout the northern half of the state, but it would appear that no general outbreak of this insect will occur in the near future although some isolated bins may need treatment before the end of the summer.

Temperature Changes

Temperature readings in corn stored in steel bins in Illinois showed that the grain three to six feet from the floor in the center of the bin reached its lowest point during the last ten days of April.

* Reported by J. M. Magner in cooperation with Ill. State Ent. Dept.

Early in June the temperature of the grain varied from the middle forties to the low eighties. With the sudden warming of the weather late in May the surface temperatures of the grain leaped from the fifties and sixties during the first half of May to the seventies and eighties by the middle of June. However, the center of the grain masses in the steel bins still remains in the forties.

Turning and Screening

Since the last part of March only eight counties have been turning and screening steel bin corn in Illinois. Of these, six stopped operations early in May. Livingston and Whiteside Counties have continued operations through June. A total of 360 bins were turned between March 28, 1942, and June 20, 1942, in the eight counties.

Experimental Fumigation

No experimental fumigations were made during the quarter since the greater volume of the grain in steel bins failed to reach temperatures of 60° F. or more.

Special Studies

Observations were continued on the bins equipped with "Sisal Craft" paper as reported on in the January-March Quarterly Report.

Since the installation of the paper covers the bins have been checked at approximately six-week intervals. The average temperatures and percent moisture for the bins at Buckley, Claytonville and Loda are shown in tables 3, 4, 5, and 6.

The experiment seems to show that the difference in grain temperature between covered bins and those not covered is very slight.

The percentage of moisture in corn in bins covered as soon as the grain was turned is less than in those not covered. However, bins in which the corn has not been turned and cleaned, but over which a cover was placed show a very much higher percentage of moisture than similar bins in which no cover was placed over the grain when the covers are allowed to remain over the grain until after the outside air begins to get warmer than the grain mass. This is very evident in bins 1037, 1038 and 1039 at Buckley and bins 67 and 69 at Claytonville in which the center of the surface grain is crusted, moldy and wet in a circle of from 6' to 16' and to a depth of 8 inches.

Hundreds of sawtooth grain beetles and cadelle beetles were observed on the surface grain under the paper in bins 69 and in smaller numbers in bins 67, 72, 1037 and 1039 and unquestionably have contributed to the condition existing in these bins.

Table 3: -- Buckley, Illinois

Butler 2,740 bushel bins
Bins 1037, 1038, and 1039 have 13½ x 13½ foot paper covers placed over grain January 28, 1942, on all bins of 1939 corn filled in 1940.

Bin No.	Temperature of corn based on the average of readings at four depths in center of bin.				Percent of moisture of corn based on the average of the top 3 cells of a 5-foot grain probe at center of bin.			
	1/28	3/2	5/5	6/12	1/28	3/2	5/5	6/12
1040	46	39	45	57	14.91	16.55	15.27	13.82
1041	42	39	48	60	12.09	14.93	14.82	15.33
1042	43	39	46	58	14.72	15.35	14.63	15.33
1037	49	42	47	60	14.66	10.62	17.30	17.31
1038	50	41	47	60	16.96	16.29	16.43	16.98
1039	48	40	47	60	15.84	16.87	16.16	18.09

Table 4: -- Claytonville, Illinois

Butler 2,000 bushel bins

Bin No.	Temperature of corn based on the average of readings at four depths in center of bin.				Percent of moisture of corn based on the average of the top 3 cells of a 5-foot grain probe at center of bin.			
	1/29	3/3	5/8	6/11	1/29	3/3	5/8	6/11
65*	49	43	51	60	13.69	12.27	12.49	12.37
66	53	40	46	57	14.45	15.98	15.23	14.78
76	50	41	47	57	16.38	15.79	15.10	13.79
67	47	40	46	59	16.98	18.08	16.06	15.27
69	50	42	46	59	16.81	17.22	15.89	16.03
72	46	39	46	58	14.86	15.16	15.46	14.83

* Grain in this bin has been turned and cleaned; all others unturned. All 1938 corn filled in fall of 1939.

Bins 67, 69 and 72 had 13½' x 13½' covers placed on surface of grain January 28, 1942.

Table 5: -- Loda, Illinois*

Butler 2,170 and Martin 2,040 bushel bins

Bin No.	Temperature of corn based on the average of readings at four depths in center of bin.				Percent moisture of corn based on the average of the top 3 cells of a 5-foot grain probe at center of bin.		
	2/13	3/30	5/5	6/12	3/30	5/5	6/12
580	40	40	48	60	11.90	11.83	12.16
581	40	39	48	61	11.79	11.61	11.75
244	39	39	49	60	12.79	12.14	12.15
242	38	40	51	60	11.14	11.16	11.35
243	39	39	50	60	11.55	12.06	12.17
245	39	41	51	66	11.26	12.75	12.87
582	36	37	49	60	11.97	11.90	12.69
583	38	39	51	63	11.19	10.97	11.39

* All bins at Loda were turned and cleaned. Bins 580 and 244 have no paper covers; however, 244 has a 13½' x 16' paper blanket at center of bin dividing the grain into an upper and a lower half. The thermocouple wires were placed through the paper. Bins 242 and 583 have covers of paper 13½' x 18'; bins 243, 245 and 582 have covers 13½' x 13½', placed over grain January 28, 1942.

Table 6: -- Comparison of bins at three locations in Illinois according to capacity, cleaned, uncleaned, covered, and not covered.*

Treatment	Number of bins	Capacity in bushels	Temperature of corn based on average of readings at four depths, center of bin				Percent moisture of corn based on average of top 3 cells of a 5-foot grain probe, center of bin			
			1/29	3/3	5/8	6/11	1/29	3/3	5/2	6/11
No cover Turned and cleaned	1	2000	49	43	51	60	12.69	12.27	12.49	12.37
No cover; not turned and cleaned	2	2000	52	41	47	57	15.46	15.89	15.17	14.29
Cover; not turned and cleaned	3	2000	48	40	46	59	16.22	16.82	15.80	15.38
			2/13	3/30	5/5	6/12		3/30	5/5	6/12
No cover Turned and cleaned	2	2100	40	39	48	60		11.85	11.72	12.46
No cover Paper thru center Turned and cleaned	1	2100	39	39	49	60		12.79	12.14	12.15
Cover Turned and cleaned	5	2100	38	39	50	60		11.42	11.77	12.09
			1/28	3/2	5/5	6/12	1/28	3/2	5/5	6/12
No cover, not turned and cleaned	3	2740	44	39	46	58**	13.91	15.61	14.91	14.83
Cover; not turned and cleaned	3	2740	49	41	47	60	15.82	14.59	16.63	17.46

* Locations: Buckley, Claytonville and Loda, Illinois.

** Each based on average of five readings in all 2740-bushel bins.

Wheat Storage

Condition of wheat in steel bins at Experimental Storage Sites*

During April and May the regular quarterly samples were taken from the bins at both Jamestown, North Dakota, and Hutchinson, Kansas. From 1 to 6 quarts of wheat from each bin were examined for insect infestation. The results show that there has been a further reduction in the already low infestation existing at Jamestown, and at Hutchinson there has been a sharp decrease in the insect population from that observed in the January samples.

At the Jamestown site, the February samples indicated that 7 percent of the bins were infested, whereas in May only 4 percent were recorded as containing living insects. None of the bins graded "weevily".

At Hutchinson, 69 percent of the bins were infested in January with 16 percent of them grading "weevily". The April samples showed that, while 60 percent of the bins still contained living insects, only 2 percent of them graded "weevily"--a reduction of 9 and 14 percent in infested and weevily bins, respectively. The intensity of infestation was reduced materially during the period January to April, the greatest observed population being only one insect per 1000 grams of wheat, based on the examination of the average samples. The reduction of infestation can be attributed largely to two factors: (1) mortality due to continued action of low temperatures in the bins, and (2) fumigation of "weevily" bins in the "fumigation when necessary" series.

At the time of writing this report, the insect infestation at both Jamestown and Hutchinson is at the lowest point observed since the bins were filled in the summer of 1941. A comparison of the infestation at the two storage sites since October 1 is given in table 7.

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* Reported by H. H. Walkden, R. B. Schwitzgebel in cooperation with the Bureau of Agr. and Chem. Engineering.

Table 7: -- Comparison of insect infestation in wheat stored in steel bins in Jamestown, North Dakota, and Hutchinson, Kansas, October, 1941, to May, 1942.

	Oct.-Nov., 1941 sampling		Jan.-Feb., 1942 sampling		Apr.-May, 1942 sampling	
	Bins infested Percent	Bu. infested Number	Bins infested Percent	Bu. infested Number	Bins infested Percent	Bu. infested Number
			Jamestown, North Dakota			
"Weevily" bins	1	2,700	1	2,700	0	0
Infested, but not weevily	18	40,000	6	16,000	4	13,500
Total infested	19	42,700	7	18,700	4	13,500
Total No. of bins sampled	139		133		139	
			Hutchinson, Kansas			
"Weevily" bins	9	31,000	16	41,000	1.5	5,300
Infested, but not weevily	31	74,000	53	137,000	58.5	159,000
Total infested	40	105,000	69	178,000	60	164,700
Total No. of bins sampled	144		135		135	

Seven species of stored grain insects were found in the samples at Hutchinson and only two species at Jamestown. These species and their comparative abundance as shown by the winter and spring quarterly samplings are shown in table 8.

Table 8: -- Comparative abundance of the various species of insects found in stored wheat, Jamestown, North Dakota, and Hutchinson, Kansas.

Species	Hutchinson, Kans.		Jamestown, N. Dak.	
	Jan., 1942	Apr., 1942	Feb., 1942	May, 1942
Rice weevil	46	46	0	0
Granary weevil	3	1	0	0
Lesser grain borer	81	3	0	0
Flat grain beetle	403	172	23	3
Rust-red flour beetle	670	28	0	0
Sawtoothed grain beetle	3	1	0	1
Foreign grain beetle	2	0	0	0
Long-headed flour beetle	3	0	0	0
Cadelle	5	1	0	0
Undetermined larvae	6	1	0	3
Total No. of living insects	1222	253	23	7

Bin Traps

At Hutchinson, two bins, which have been tightly caulked so that the only means by which insects can gain entrance is through the ventilator, have been fitted with ventilator traps to retain any insects entering in this manner. These traps consist of quart jars sealed into the ventilator caps. A small amount of wheat is put in the jars. The traps are examined daily and the number and kind of stored grain insects entering through the ventilator are recorded. Observations were begun on April 2. Booklice were taken for the first time on April 6, and have become more abundant as the season advanced, reaching a peak on June 2, when approximately 1000 specimens were taken during a 24-hour period. Mites first appeared on April 10, and have been moderately abundant throughout the period, the largest catch being approximately 100 individuals.

Of the economic species of stored grain insects, the flat grain beetle was taken for the first time on April 17, the sawtoothed grain beetle on May 13, the Indian meal moth on May 14, the lesser grain borer on May 15, and the foreign grain beetle on June 15. Up to the end of June, however, no large migrations of stored grain insects have occurred, as shown either by the traps or by observation at the bin site. A small number of flat grain beetles were noted on June 20, crawling about on the outside of one of the bins which have perforated walls.

Revolving Insect Trap

A trap consisting of two nets revolving on 6-foot arms was constructed with the object of making observations on the flight of stored grain insects. The apparatus is driven by a 1/2-H. P. electric motor connected to an automobile differential. The nets revolve about 50 r.p.m. In this manner, flights of insects at two levels can be studied. This trap was placed in operation at Hutchinson on April 1 and has been operated on favorable days during the last three months. Large numbers of insects have been caught, but to date only 3 species of stored grain insects have been taken: May 26, one rust-red flour beetle; June 11, one rice weevil; June 12, one lesser grain borer. Frequent periods of cool, rainy weather have no doubt inhibited migration to a large extent.

Covered Bins

The surface of the grain in one bin is covered with Kraft paper treated with nicotine sulphate. The edge of the paper is sealed to the bin wall with caulking compound. Observations made in this bin during May showed that large numbers of flat grain beetles and booklice have been killed on the surface of the treated paper. Inasmuch as the cover is tightly sealed to the walls of the bin, it is quite probable that these insects entered the bin from an outside source and were killed on coming in contact with the nicotine sulphate.

Effect of Turning, Cleaning, and Fumigating Insect-Infested Wheat

One of the bins in the series receiving two annual surface treatments of oil developed abnormally high temperatures during November, 1941, as a result of insect infestation. The bin was spot-fumigated in the infested area on December 16, 1941, using carbon disulphide. Subsequently a gradual drop in temperature was noted, but by the middle of March, 1942, however, the temperature had again risen to dangerous levels. On examination, an area of moldy, crusted grain was found on the surface in the southwest quadrant of the bin. Approximately 25 bushels of spoiled grain were removed from this area, the spoilage varying in depth from 2 to 18 inches. An insect-moisture traverse of the bin revealed that about 600 bushels of grain were heavily infested with insects, and that while the moisture content of the grain on the surface was about 16 percent, the grain in the heavily infested portion contained no greater amount

of moisture than that in the uninfested portion of the bin. The bin was fumigated on March 17, using Dowfume Br-10 at the rate of 2 gallons per 1000 bushels of wheat. An insect traverse after this fumigation revealed that insects had survived in about 100 bushels of grain located in an area on the south side of the bin about 3 feet below the surface. Fat acidity determinations made by the Agricultural Marketing Service indicated that the grain in the infested portion had nearly reached the upper limit for safe storage. Because of this condition, it was deemed necessary to turn, clean, and fumigate the grain in order to prevent serious deterioration. On April 15, the grain was run over an 8-foot screen and put into another bin. Insect traverses made before and after turning and cleaning showed that a reduction of about 90 percent in the insect population had been accomplished by the process. Before cleaning, the insect population amounted to 8 insects per 1000 grams of wheat, while after cleaning, samples of the grain contained only 1 insect per 1000 grams. Traverses made after turning and cleaning showed that the center of infestation had been broken up and the few remaining insects were widely scattered throughout the grain mass. Immediately after the grain was turned and cleaned, it was fumigated with carbon disulphide at the rate of 3 gallons per 1000 bushels and the surface re-oiled. The original condition of the bin, together with the changes resulting from the various treatments are shown in figs. 1, 2, and 3.

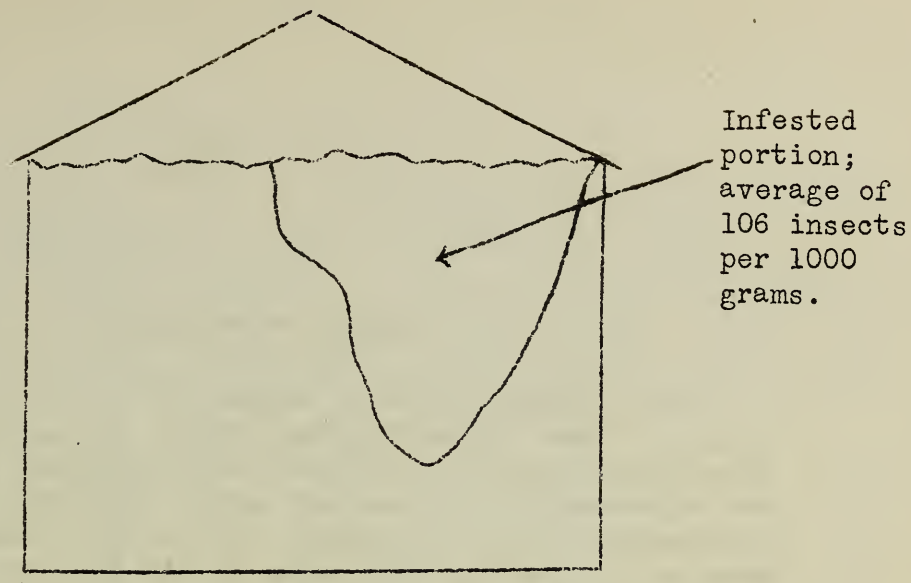

Fig. 1:--Original center of infestation before fumigation, December, 1941.

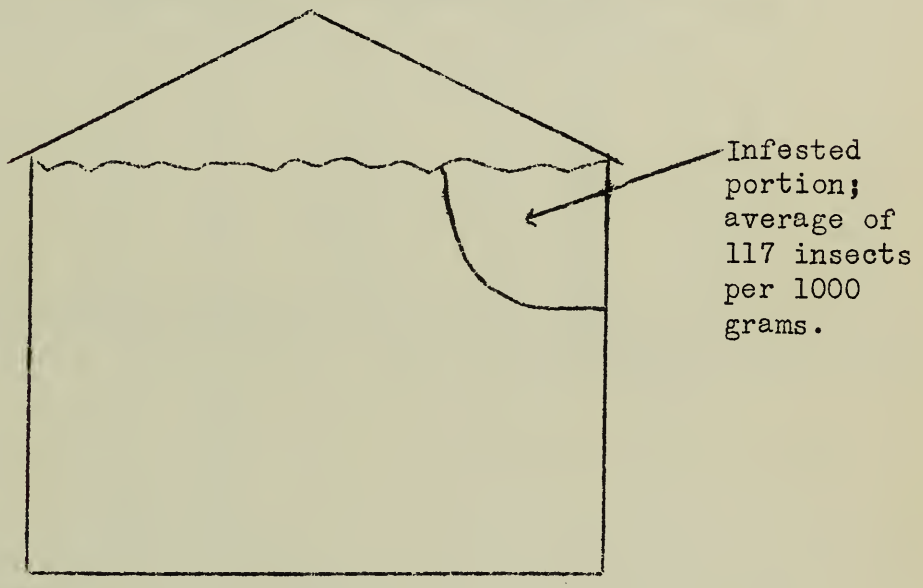

Fig. 2:--Center of infestation before fumigation, March, 1942.

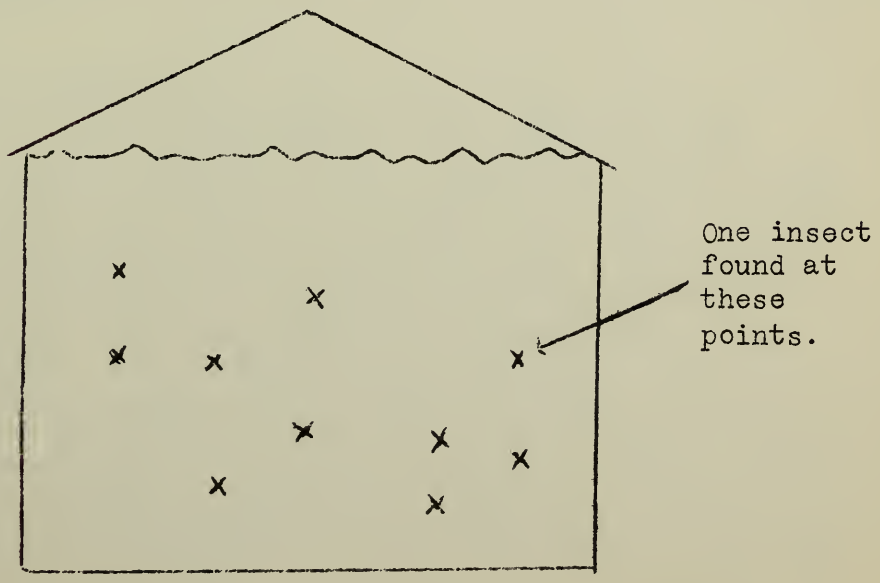

Fig. 3:--Distribution of insects after turning and cleaning, April, 1942.

Effect of Fumigation on Germination

The question has been raised as to the effect of various fumigants on wheat stored in steel bins. During the storage period at Hutchinson, certain bins have been fumigated with carbon disulphide, and others with a mixture of carbon tetrachloride 22.5%, ethylene dichloride 67.5%, and methyl bromide 10% (trade name Dowfume Br-10). Germination samples were taken at the time the bins were filled and again in April, 1942. The bins were fumigated once during that interval. The results are tabulated in table 9.

Table 9: -- Effect of fumigation on germination of wheat.

Fumigation with Dowfume Br-10 2 gals. per 1000 bu.					Fumigation with carbon disulphide 3 gals. per 1000 bu.				
		Germination					Germination		
Bin No.	Capacity (bu.)	June, 1941 (%)	April, 1942 (%)	Variation (%)	Bin No.	Capacity (bu.)	June, 1941 (%)	April, 1942 (%)	Variation (%)
1-2	1000	80	82	+2	1-3	1000	85	81	-4
2-5	"	70	53	-17	2-4	"	85	80	-5
2-7	"	84	78	-6	2-6	"	80	78	-2
4-10	"	80	69	-11	4-11	"	70	54	-16
2-12	"	76	79	+3	3-13	"	85	73	-12
3-12	"	84	82	-2	4-12	"	76	78	+2
9-13	"	87	86	-1	1-4	"	85	83	-2
Mean	"	80.1	75.6	-4.5		"	80.9	75.1	-5.8
7-2	2740	88	87	-1	9-4	2740	86	88	+2
9-1	"	78	74	-4	9-5	"	81	82	+1
9-2	"	80	79	-1	5-4	"	82	74	-8
9-3	"	71	71	0	9-7	"	89	79	-10
10-1	"	76	44	-32	10-5	"	80	42	-38
10-2	"	85	80	-5	10-4	"	85	87	+2
10-3	"	78	63	-15	6-5	"	82	78	-4
Mean	"	80.6	69.9	-10.7		"	82.9	75.1	-7.8
6-13	4000	82	44*	-38					
5-12 ø	4600	59	16	-43					
5-10	5000	88	71	-17					
6-12	5000	86	62**	-24					
Mean		78.8	64.3	-14.5					

ø Bolted tank, sealed with rubber gaskets.

* Average of 3 samples.

** Average of 2 samples.

From the table it may be seen that the greatest reduction in germination occurred in the larger-capacity bins (4000 to 5000 bushels) fumigated with the Dowfume Br-10. However, no bins of like capacity were available for fumigation with carbon disulphide; hence it is not determined what the effect of it would have been in large masses of grain under the conditions imposed by steel bin storage. With bins of 1000- and 2740-bushel capacity, there appears to be little difference in the effect on germination between carbon disulphide and Dowfume Br-10. It is possible that the larger-capacity bins retain the gas for a longer period, thus prolonging the interval during which the grain is exposed to the deleterious effect of heavy concentrations of the fumigant. Germination samples were taken from the surface, middle and bottom of the bins to determine if the fumigant affected germination differently in different parts of the bins. The results of these tests follow.

Germination Tests of Wheat from Hutchinson, Kansas.*

Samples of wheat taken from the metal storage bins at Hutchinson, Kansas, were tested for the effect of the fumigants used, upon germination. These samples were taken from one side and center of each of eight different bins, at three elevations. Five of these bins were treated on November 20, 1941, with Dowfume Br-10 using a dosage of 2 gallons per thousand bushels. The other three were treated on July 20, 1941, with 3 gallons of carbon disulphide per thousand bushels. Six samples of wheat were taken from each bin, one each from the side and center of the bin at 1, 7, and 13 feet from the bottom of the bin. Thus a total of 48 samples were included in these tests.

In making germination tests the standard method used in all our laboratory tests was used. That is, 4 replicates of 100 grains of wheat were used for each test. These were placed in paper toweling and examined the third and sixth day. Table 10 summarizes the results of these tests. Each figure listed is the average of four replicates.

These tests show that there is no significant difference in the effect of either of the two fumigants at different levels in the bin. A significant difference is noted between the samples taken from the side and center of bins treated with Dowfume Br 10. It will be noted that all samples taken from the sides of bins gave a lower percentage of germination than samples taken from the center of the bins. The causes for this difference are not clear. One hypothesis might be that in spraying the fumigant on the top of the grain, a heavier dosage was applied at the sides than at the center of the bin. Another might be the effect of temperature which undoubtedly is higher on the sides of the bin than in the center.

The bins treated with Dowfume Br-10, showed some injury to the wheat, as compared with the checks, as well as the carbon disulphide treated wheat. It is difficult to understand the difference in the percentages of germination of the checks. These checks were taken from each bin prior to their treatment. No injury was sustained by the wheat treated with carbon disulphide.

In one bin treated with Dowfume Br-10 the germination has been reduced to 16 and 19%. This bin was sealed immediately after treatment. Whether this injury to germination is entirely due to the fumigant in combination with the sealed bin, is doubtful. It should be noted that the check sample taken before the bin was treated or sealed, gave only a 59% germination.

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* Reported by J. C. Frankenfeld.

Table 10: -- Summary of germination tests from Hutchinson, Kans. binsite. Samples removed from bins 6/5/42. (Each figure represents an average of four samples of wheat of 100 kernels each.)

Bin No.	Fumigant used	Percentage of germination of wheat from: Side of Bin: Number of feet from bottom of bin: 1	7	13	Average	Center of Bin: Number of feet from bottom of bin: 1	7	13	Average	Checks
5-12*	Dowfume Br-10	1	31	16	16	7	35	14	19	59
6-13	" " "	62	71	70	68	75	75	74	75	82
10-1	" " "	67	28	48	48	80	43	48	57	76
10-3	" " "	84	72	69	75	83	80	81	81	78
11-1	" " "	71	72	62	68	83	88	69	80	89
	Average	57	55	53	55	66	64	57	62	77
6-5	Carbon-disulphide	93	78	80	87	95	84	82	87	82
9-5	" "	90	88	76	85	93	77	86	85	81
9-7	" "	90	87	81	86	88	87	79	85	89
	Average	91	84	79	86	92	83	82	86	84

Bins fumigated with Dowfume Br-10 were treated Nov. 20, 1941.

Bins fumigated with Carbon disulphide were treated July 20, 1941.

* Sealed bin.

Routine Fumigation and Surface Treatment of Bins in the Management Series*

As called for in the plan of work, a series of bins, nine in number, receive two fumigations annually, one in June and the other in September. These bins, while not requiring a fumigation at this time, were nevertheless given a fumigation in accordance with the schedule. Check boxes placed in the bins showed that, at a dosage of 2 gallons per 1000 bushels, Dowfume Br-10 gave uniformly good kills in all parts of the bins.

Another series of bins, nine in number, have been designated to receive an oil spray on the surface of the grain twice annually--once in June and again in September, at the rate of 2 quarts of oil per 1000 bushels of grain. The oil treatment of corn bins has proved highly successful in Illinois and Iowa, as a means of reducing surface re-infestation, and for this reason was included in the wheat storage project. The oil treatment has been applied at both Jamestown and Hutchinson. At Jamestown, Texaco Corvus oil was used, and at Hutchinson, Standard Diamond paraffin. Observations in bins so treated show that the oil penetrates very little--three to four kernels deep at the most. To date none of the grade samples submitted from oil-treated bins have been graded down because of an objectionable oily odor.

Experimental Fumigation

Experimental fumigations are now in progress at Hutchinson to determine the minimum lethal dosage of several fumigants including several new mixtures which have shown promise in laboratory tests. Several types and sizes of bins are being used to test the influence of caulking, bin capacity, surface area, etc., on dosage, gas retention, and the like.

The following fumigants are included in the tests, and the minimum lethal dosages will be established as rapidly as available bins will permit:

1. Ethylene dichloride 75%, carbon tetrachloride 25% (Dowfume 75)
2. Ethylene dichloride 67.5%, carbon tetrachloride 22.5%, methyl bromide 10% (Dowfume Br-10)
3. Ethylene dichloride 90%, methyl bromide 10% (Dowfume E)
4. Propylene dichloride 67.5%, carbon tetrachloride 22.5%, methyl bromide 10% (Dowfume Br-10-S)
5. Propylene dichloride 90%, methyl bromide 10% (Dowfume P)
6. Methylene chloride 90%, methyl bromide 10% (Dow methylene chloride mixture)

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* Reported by H. H. Walkden and R. B. Schwitzgebel.

7. Dowfume C (Analysis not yet received from Dow Chemical Co.)
8. Trichloroacetonitrile
9. Acrylonitrile
10. Cyanogen chloride - hydrocyanic acid mixture (Saftifume briquettes)
11. Surface toxicant - Dowspray 208
12. Surface toxicant - Dow K-1127

The experimental fumigation work was begun on June 9, the first effort being directed at the determination of the minimum lethal dosage of the ethylene dichloride-carbon tetrachloride mixture in various types and sizes of steel bins. In determining the minimum lethal dosage and the retention of the gas in the bins, the following method is being employed:

Three 1000- and three 2740-bushel bins with caulked floors and walls were fumigated with a dosage of 4, 5, and 6 gallons per 1000 bushels, respectively. At the same time one 2740-bushel bin with no caulking and one 2740-bushel bin with caulked floor only were fumigated with a dosage of 6 gallons per 1000 bushels to determine any differences due to caulking. Five check probes were inserted in the grain before fumigation--in the center, and in the north, south, east, and west quadrants of the bin. Gelatine capsules with bolting cloth ends, containing living insects, were put in cells in the probes at the floor, 4-, 8-, and 12-foot levels in 2740-bushel bins, and in the 1000-bushel bins the check cells were located at the floor, 2-, 4-, and 6-foot levels. The five check probes were removed 72 hours after fumigation and one fresh probe was inserted in the center of each bin. This process of inserting a fresh check probe every 72 hours is continued until no further kill is obtained, indicating that the residual gas has disappeared. The bins are then used for further experiments.

The results to date show that the ethylene dichloride-carbon tetrachloride mixture is equally effective in all types of bins in dosages as low as 4 gallons per 1000 bushels, and also that the gas is retained in the bins in lethal concentrations for more than two weeks. Bins fumigated on June 10 still contained a lethal concentration at the end of the month. Final results will be included in a later report. Three mixtures have been tested so far, and the results are given in table 11.

Table 11: -- Determination of minimum lethal dosage of various fumigants.

Caulking	Capacity (bu.)	Fumigant used	Dosage per 1000 bu. (gals.)	Mortality (%)	Check--mortality (%)
Floor, walls	1000	Ethylene dichloride-carbon tetrachloride mixture	4	91*	7
" "	1000	" " " " "	5	87	7
" "	1000	" " " " "	6	98	7
" "	2740	" " " " "	4	97	7
" "	2740	" " " " "	5	90	7
" "	2740	" " " " "	6	98	7
Floor only	2740	" " " " "	6	98	7
None	2740	" " " " "	6	100	7
Floor, walls roof	1000	Cyanogen chloride - HCN (Saftifume briquettes)	4**	27	7
Floor, walls	1000	Methylene chloride 90%, methyl bromide 10%	2	100	7
" "	2740	" " " " "	2	100	7

Notes: * The small percentage of insects surviving the fumigation were found in the cells from the floor levels near the junction of the bin floor and wall.

** This material was used at the rate recommended by the manufacturer--4 briquettes, 2 gals. HCl. - 1½ gals. water.

It may be noted from the table that the test with Saftifume briquettes gave very poor results as compared with the other mixtures. No kills were obtained below the surface 2 inches, indicating that the gas does not penetrate downward in the grain, making it unsuited to this type of fumigation.

An Air-Pressure Apparatus for the Application of Liquid Fumigants

The apparatus described in this report was developed, in cooperation with the Bureau of Agricultural Chemistry and Engineering, to meet the need for safe, efficient and comparatively inexpensive equipment for the application of liquid fumigants to grain stored in steel bins.

The outfit consists essentially of two steel pressure tanks (range boilers), one to contain compressed air and the other for the fumigant. These are connected with an air line, together with the necessary valves, pressure gauges, etc. The tanks are mounted on a wooden frame, and the total weight, empty, is approximately 175 pounds. Provision is made for filling the fumigant tank from the supply barrel by means of air pressure, thus eliminating the necessity of exposing the fumigant to the open air. This method of transferring the fumigant reduces the hazard to the operator.

In operation, the compressed air tank is filled to 150 pounds pressure. The required amount of fumigant is put into the fumigant tank, and compressed air is then admitted to it from the supply tank, thus forcing the fumigant out through the delivery hose. With 20 pounds air pressure in the fumigant tank, the rate of flow is approximately one gallon per minute.

When applying inflammable fumigants, such as carbon bisulphide, the apparatus should be properly grounded, including the delivery nozzle, as the friction of the liquid is liable to develop a static electricity charge.

Some of the advantages of this fumigating equipment include low initial cost, low maintenance and operating expense, simplicity of construction and operation and mobility.

A manuscript describing and illustrating the above fumigator is being prepared for publication in the ET series of the bureau.

Sampling Methods

In the preceding report, mention was made of a study then in progress to determine the amount of variation between "average" samples. Such samples are taken from all of the bins at both Jamestown and Hutchinson at quarterly intervals. The samples are drawn from ten places in the bin by means of a grain probe, and the resulting composite or "average" sample includes grain from the center, north, east, south, and west portions of the grain mass, and aggregates 6 quarts of grain. Two bins at Hutchinson were selected for study and twenty-five average samples were taken from each of them. The portions representing the center, north, east, south, and west portions of the grain mass were kept separate so that centers of insect infestation could thus be located. In this manner, the number of living and dead insects in five locations in the bins was determined. The results are given in tables 12 and 13. It may be seen that:

1. By far the greatest concentrations of insects (91%) were located in the central portion of the bins.

2. Average samples, under the conditions of infestation in these bins, vary much less than was expected, and more than two-thirds of them fall within the limits set by the standard deviations. Thus it appears that within the practical limits imposed by available time and the mechanics of sampling, the average samples yield fairly reliable estimates of insect populations.

With regard to the species of stored grain insects found in the samples, the flat grain beetle was the dominant species, with the rust-red flour beetle ranking second. The list of species and their comparative abundance are given in table 14.

Table 12: -- Variation in insect infestation in average samples taken from bin 5-6, Hutchinson, Kansas, April, 1942.

Sample No.	Location of individual probe samples										Composite or "Ave." Sample	
	Center		North		East		South		West			
	Live	Dead	Live	Dead	Live	Dead	Live	Dead	Live	Dead	live	dead
1	5	5	0	0	0	0	1	1	0	1	6	7
2	5	16	0	0	1	1	0	2	0	1	6	20
3	20	30	1	1	0	0	1	3	0	1	22	35
4	0	2	0	0	0	0	0	2	0	0	0	4
5	3	6	0	1	0	2	1	3	0	0	4	12
6	6	11	0	0	0	0	0	2	0	0	6	13
7	1	2	0	2	0	0	0	4	1	1	2	9
8	1	5	0	1	0	0	0	6	0	2	1	14
9	3	4	0	1	1	0	0	3	0	1	4	9
10	2	2	0	1	0	0	0	3	1	0	3	6
11	11	10	0	1	0	1	0	2	0	1	11	15
12	9	27	0	1	0	2	0	9	0	0	9	39
13	0	22	0	1	0	0	0	2	0	0	0	25
14	0	28	0	0	0	2	0	0	0	0	0	30
15	0	11	0	3	0	0	0	2	0	1	0	17
16	7	4	0	1	0	0	0	6	0	0	7	11
17	3	4	0	1	1	0	1	4	0	0	5	9
18	17	15	0	2	0	0	0	1	0	2	17	20
19	9	10	0	0	0	1	0	2	0	0	9	13
20	0	7	0	0	0	0	1	2	0	0	1	9
21	12	26	0	1	0	0	0	3	0	1	12	31
22	7	18	0	0	0	0	0	4	0	2	7	24
23	3	6	0	0	0	2	0	3	0	0	3	11
24	2	2	0	0	0	0	0	0	0	0	2	2
25	14	31	0	1	1	0	0	1	0	1	15	34
Totals	140	304	1	19	4	11	5	70	2	15	152	419

Mean -- 6.08 ± 1.15

Standard deviation -- 5.75

Range -- 0-22 insects per average sample

Percentage of samples infested -- 84

Table 13: -- Variation in insect infestation in average samples taken from bin 10-10, Hutchinson, Kansas, April, 1942.

Sample No.	Location of individual probe samples										Composite or "Ave." sample	
	Center		North		East		South		West			
	Live	Dead	Live	Dead	Live	Dead	Live	Dead	Live	Dead	Live	Dead
1	7	13	0	2	0	0	0	0	0	0	7	20
2	17	49	1	2	1	0	1	3	0	1	20	54
3	3	15	0	2	0	1	0	1	0	0	3	19
4	6	9	0	2	0	0	0	2	0	1	6	14
5	11	14	0	0	1	2	1	1	0	0	13	17
6	2	9	0	1	0	0	0	0	0	0	2	10
7	2	4	0	0	0	1	0	1	0	0	2	6
8	3	32	0	0	1	0	0	2	0	0	4	34
9	13	10	0	5	0	0	3	1	0	3	16	19
10	1	5	0	1	0	0	0	0	0	0	1	6
11	0	11	1	3	0	2	0	2	0	0	1	18
12	3	7	0	0	0	1	0	1	0	0	3	9
13	0	13	0	1	0	0	0	3	0	0	0	17
14	4	17	0	0	0	0	0	4	0	3	4	24
15	7	16	0	0	0	2	0	0	0	1	7	19
16	5	8	0	1	0	1	0	2	0	0	5	12
17	6	6	0	1	0	0	0	0	0	0	6	7
18	2	5	0	2	0	0	0	1	0	0	2	8
19	1	12	2	2	0	0	0	2	0	1	3	17
20	1	18	0	2	0	0	0	1	0	0	1	21
21	4	18	0	0	0	1	0	0	0	0	4	19
22	7	10	1	0	0	0	0	0	0	0	8	10
23	1	3	0	1	0	0	0	2	0	1	1	7
24	2	8	0	1	0	0	0	1	0	0	2	10
25	3	11	0	0	0	0	0	0	0	1	3	12
Totals	111	328	5	29	3	11	5	29	0	12	124	409

Mean - 4.96 ± 0.95 insects per sample

Standard deviation - 4.88

Range - 0-20 insects per average sample

Percentage of samples infested - 96

Table 14: -- Comparative abundance of the various species found in 50 average samples, Hutchinson, Kans. April, 1942

Species	Living (Number)	Living (Percent)	Dead (Number)	Total
Flat grain beetle	194	68.1	91	285
Rust-red flour beetle	78	14.7	452	530
Sawtoothed grain beetle	3	17.6	14	17
Lesser grain borer	1	1.3	74	75
Rice weevil	0	0	161	161
Granary weevil	0	0	29	29
Cadelle	0	0	6	6
Foreign grain beetle	0	0	1	1
Totals	276	25.0	828	1104

The above sampling was done before the spring rise in bin temperatures had begun. It is planned to repeat the work later in the season, when the bin temperatures have reached their highest levels.

Effect of Grain Moisture on the Development of Stored Grain Insects.*

In a previous report it was indicated that in order to definitely establish the effect of grain moisture on the development of stored grain insects it was necessary to take into consideration, the effect of temperature as well. By using 500 cc Erlenmeyer flasks, each holding 200 grams of grain, it was possible to maintain a large number of cultures of grain infesting insects in incubators under constant temperature and moisture conditions.

Wheat samples with a moisture content of 9, 10, and 11%, infested with six common grain infesting insects were maintained at constant temperatures of 65, 70, and 75° F. One hundred adults of each of the following species, the granary weevil, rice weevil, confused flour beetle, rust red flour beetle, lesser grain borer and the sawtoothed grain beetle and 20 adults of Cynaeus angustus were used to establish cultures in each grain moisture and temperature variant.

* Reported by R. T. Cotton and J. C. Frankenfeld.

In the report for the preceding quarter it was noted that at the end of nine weeks no reproduction had taken place in any of the cultures, although considerable mortality occurred with many of the species. The percentage of survival in general was in direct proportion to the moisture content, the temperature factor having no apparent influence.

The cultures have been kept under observation during the past quarter with the results indicated by the data of tables 15, 16, and 17. The cultures maintained at a constant temperature of 65° F. were discarded at the end of 13 weeks owing to the fact that due to the increasing seasonal temperatures it was impossible to maintain this temperature.

It will be noted from the data of table 15 that no development occurred with any species during the 13 week period during which cultures were maintained at 65° F. regardless of the moisture content of the grain. A gradual increase in mortality occurred with all species and at all moisture contents. In the 9% and 10% moisture wheat the rice weevil adults were all dead at the end of the 13th week.

As shown by the data of table 16 conditions in the various cultures maintained at 70° F. were somewhat the same as in those maintained at 65° F. however, at the end of 19 weeks reproduction of the granary weevil had taken place in 10% and 11% moisture wheat and of the rice weevil in 11% moisture wheat.

In the cultures maintained at constant temperatures of 75° F. the mortality of adult insects was somewhat greater at the end of 19 weeks doubtless due to the greater activity of the insects at this temperature, table 17. Reproduction of the granary weevil occurred in both the 10% and 11% moisture wheats. It is significant that at these temperatures no reproduction of any insect of the "bran bug" type occurred regardless of the moisture content of the grain.

With the discarding of the series of cultures that had been held at a constant temperature of 65° F., a new series of cultures was prepared and held at a constant temperature of 90° F. As indicated by the data of table 18 the effect of the increase in temperature on the reproductive capacity of the several species is quite marked. After nine weeks, reproduction of the rice weevil, the sawtoothed grain beetle and the rust red flour beetle occurred even in the 9% moisture wheat and of all other species tested in the 10% and 11% moisture wheat.

Table 15: -- Showing the percentage of survival of various species of stored grain insects reared in 9, 10, and 11% moisture wheat at 65° F.

Species of insect	Percentage of survival after: 1 week	3 weeks	5 weeks	7 weeks	9 weeks	11 weeks	13 weeks
9% wheat							
Granary weevil	92	80	70	57	54	42	37
Rice weevil	39	31	23	11	8	3	0
Confused flour beetle	99	99	99	88	76	42	37
Lesser grain borer	96	74	61	53	46	46	46
Sawtoothed grain beetle	100	100	97	94	87	72	62
Rust red flour beetle	94	66	38	28			
10% wheat							
Granary weevil	95	90	90	81	77	70	61
Rice weevil	60	45	32	12	10	3	0
Confused flour beetle	97	91	90	83	69	56	52
Lesser grain borer	91	74	54	48	44	39	37
Sawtoothed grain beetle	97	87	76	61	45	29	20
Rust red flour beetle	82	62	38	32			
11% wheat							
Granary weevil	100	96	96	95	91	86	78
Rice weevil	81	75	61	37	34	28	22
Confused flour beetle	98	92	91	88	79	76	75
Lesser grain borer	41	20	10	8	8	6	6
Sawtoothed grain beetle	97	94	85	80	79	69	58
Rust red flour beetle	100	96	92	86			

Table 16:--Showing the percentage of survival of various species of stored grain insects reared in 9, 10, and 11% moisture wheat at 70° F.

Species of insect	Percentage of survival after: 1 week	3 weeks	5 weeks	7 weeks	9 weeks	11 weeks	13 weeks	15 weeks	17 weeks	19 weeks	Number of progeny after 19 weeks
9% wheat											
Granary weevil	90	81	81	75	71	42	30	23	12	10	
Rice weevil	45	30	4	2	0						
Confused flour beetle	100	92	87	76	54	32	24	20	12	8	
Lesser grain borer	35	6	2	0							
Sawtoothed grain beetle	97	92	85	77	60	41	27	12	3	3	
Rust red flour beetle	100	97	36	24	18	9	5				
10% wheat											
Granary weevil	92	91	88	85	80	73	65	45	29*		15
Rice weevil	57	50	34	18	9	2	0				
Confused flour beetle	95	91	84	83	80	69	66	40	28	21	
Lesser grain borer	32	16	10	9	9	8	8	8	8	8	
Sawtoothed grain beetle	93	77	69	55	43	30	22	14	8	5	
Rust red flour beetle	100	87	33	16	8	2	0				
11% wheat											
Granary weevil	96	92	92	91	91	85	81*				125
Rice weevil	76	73	58	49	29	14	9*				87
Confused flour beetle	97	96	96	94	92	89	82	76	67	61	
Lesser grain borer	62	50	47	45	44	44	42	40	40	40	
Sawtoothed grain beetle	94	86	76	71	65	52	46	36	29	18	
Rust-red flour beetle	97	96	77	59	48	34	26				

* Discontinued because progeny were recovered.

Table 17:--Showing the percentage of survival of various species of stored grain insects reared in 9, 10, and 11% moisture wheat at 75° F.

Species of insect	Percentage of survival after 1 week	3 weeks	5 weeks	7 weeks	9 weeks	11 weeks	13 weeks	15 weeks	17 weeks	19 weeks	Number of progeny after 19 weeks
9% wheat											
Granary weevil	96	91	88	85	58	24	14	0			
Rice weevil	66	44	21	8	1	0					
Confused flour beetle	100	92	80	60	35	18	12	9	7	5	
Lesser grain borer	82	10	1								
Sawtoothed grain beetle	100	97	93	88	66	40	26	20	5	5	
Rust red flour beetle	97	96	80	63	42	28	24				
10% wheat											
Granary weevil	96	95	94	88	83	69	50	31*			8
Rice weevil	73	49	33	16	0						
Confused flour beetle	97	92	86	82	76	56	52	32	24	19	
Lesser grain borer	68	8	3								
Sawtoothed grain beetle	99	84	65	54	39	22	17	8	3	0	
Rust red flour beetle	100	99	88	78	60	46	40				
11% wheat											
Granary weevil	87	83	83	79	79	79	69	67	63*		4
Rice weevil	79	71	53	35	21	5	2	0			
Confused flour beetle	99	95	92	87	86	78	72	64	52	47	
Lesser grain borer	2	0									
Sawtoothed grain beetle	99	93	86	69	62	50	38	26	15	8	
Rust red flour beetle	97	92	75	63	40	22	19				

* Discontinued because progeny were recovered.

Table 18:--Showing the percentage of survival of various species of stored grain insects reared in 9, 10, and 11% moisture wheat at 90° F.

Species of insect	Percentage of survival after: 1 week	2 weeks	3 weeks	4 weeks	5 weeks	6 weeks	7 weeks	8 weeks	Total number of progeny after 8 weeks
9% wheat									
Granary weevil	86	73	69	64	52	35	18	11	0
Rice weevil	98	98	94	83	72	54	36	12*	12
Confused flour beetle	98	98	96	95	91	87	86	83	0
Lesser grain borer	97	96	92	84	76	68	64	60	0
Sawtoothed grain beetle	97	83	58	32*					33
Rust red flour beetle	76	33	19	5*					30
10% wheat									
Granary weevil	90	84	77	73	71	66*			9
Rice weevil	99	99	98	96	94	86*			413
Confused flour beetle	98	98	96	96*					66
Lesser grain borer	94	93	93	92	85*				694
Sawtoothed grain beetle	100	98	83	75*					106
Rust red flour beetle	85	79	70	59	57	52	48	48	0
11% wheat									
Granary weevil	98	93	86	76	73	68	67*		7
Rice weevil	100	99	97	97	94*				984
Confused flour beetle	97	96	93	92	91*				124
Lesser grain borer	98	98	97	95	92*				240
Sawtoothed grain beetle	90	84	72	53	31	23	15*		27
Rust red flour beetle	76	51	37	26	15	10	4	0	0

* Discontinued because progeny were recovered.

Tests of Various Treatments for Wooden Grain Bins to Prevent Burrowing of Grain-infesting Insects*

The proposed use of large numbers of wooden bins for storing surplus grain in the hard winter wheat region has suggested the desirability of treating the inside surfaces of the bins with some chemical that will prevent such insects as the cadelle and the lesser grain borer from riddling the wooden floors and side walls with their burrows. The habit of these two insects of burrowing in the walls and floors of wooden grain bins and remaining concealed within the woodwork for long periods provides one of the important sources of infestation of new grain stored in wooden bins.

For the purpose of the test 60 model wooden bins 7" x 7" x 6½" were constructed of pine wood. All joints and cracks were carefully filled with liquid wood, and the inner surfaces of the walls and floors of the bins given a coating of one of the repellents as indicated in table 19.

The model bins were then filled with wheat heavily infested with the cadelle and the lesser grain borer. All bins will be examined at monthly intervals to determine which, if any, of the treatments are of value. In addition it is planned to test the efficacy of treatments that have been recommended to preserve wood from the attack of such insects as termites, wood borers, etc. in order to determine whether or not such treatments will be useful also in protecting wood from the burrowing of grain infesting insects.

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* Reported by R. T. Cotton and H. D. Young.

Table 19:--Type of treatment given to floors and walls of model wooden grain bins.

No. of bin	Solution used to treat walls and floor
1 & 2	White lead paint
3 & 4	Boiled linseed oil
5 & 6	Spar varnish
7 & 8	Nitroethane
9 & 10	K1127
11 & 12	Dow spray 208
13 & 14	Pyrofume 20
15 & 16	Lethane 384 special
17 & 18	Nicotine sulphate 40
19 & 20	Thanite
21 & 22	Paraffin mineral oil
23 & 24	White wash
25 & 26	White paint + 10% nitroethane
27 & 28	" " + 10% K1127
29 & 30	" " + 10% Dow Spray 208
31 & 32	" " + 10% Pyrofume 20
33 & 34	" " + 10% Lethane 384 special
35 & 36	" " + 10% Nicotine sulphate 40
37 & 38	" " + 10% Thanite
39 & 40	" " + 10% oil of winter green
41 & 42	" " + 10% oil of anise
43 & 44	Paraffin oil + 10% Lethane 384 special
45 & 46	" " + 10% Pyrofume 20
47 & 48	" " + 10% nicotine sulphate 40
49, 50, 51, & 52	Melted paraffin
53 & 54	1% nicotine sulphate 40 in water
55, 56, 57, 58, 59 and 60	Checks untreated

Biological Notes*

The duration of the developmental stages of the black flour beetle, Tribolium madens Charp., under a number of conditions of temperature and moisture have been determined. Development is speeded up markedly at higher moisture levels of food and atmosphere. At moisture levels of 89% relative humidity or higher (actually at a saturation deficit of -2.5 mm. at each temperature) development is completed in about 44 days at 77° F., in 29 days at 86° F., and in 23 days at 95° F. At 77° F. but with the relative humidity reduced to 5 percent development requires as much as 62 days.

At a relative humidity of 75 percent, development at 72° F. was complete in 93 days, at 81° F. in 37 days, and at 90° F. in 27 days.

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* From report of observations made by A. W. Buzicky under the direction of Dr. H. H. Shepard, University of Minnesota.